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Effect of flubendiamide and a lactic acid bacterial formulation on leaffolder, *Cnaphalocrocis medinalis* Guenee and natural enemies in rice

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Abstract
Pesticides are predominantly used to manage rice leaffolder, *Cnaphalocrocis medinalis* Guenee, killing both pests and natural enemies. Used as biofertilizers, phytostimulators, rhizoremediators and biopesticides in crop production, lactic acid bacteria (LAB) are likely to reduce the impact of pesticides on natural enemies, if compatible. Flubendiamide in combination with a LAB formulation was evaluated against *C. medinalis* and natural enemies in in replicated field trials. Flubendiamide 20 WG @ 25 g a.i. ha^{-1} + LAB reduced the leaffolder damage by 72.03 – 78.48 per cent, whereas flubendiamide 20 WG @ 25 g a.i. ha^{-1} alone by 65.39 – 69.0 per cent, and LAB alone by 28.11 – 31.74 per cent, compared to the control plots. Coccinellids, spiders and rove beetle were more abundant in plots where LAB was sprayed (3.49, 6.96, 8.66 / 10 hills respectively) than in flubendiamide sprays with or without LAB (1.47 – 2.48, 3.54 – 5.18, 5.02 – 6.70 / 10 hills respectively).

Keywords: Flubendiamide, lactic acid bacteria, rice leaffolder, natural enemies

Introduction
Insect pests are major constraints limiting rice (*Oryza sativa* L.) productivity besides diseases and weeds [1]. Among them, rice leaffolder, *Cnaphalocrocis medinalis* Guenee is a major pest, especially when high level of nitrogenous fertilizers are applied in cloudy weather with low sunlight [6]. Its larvae fasten the edges of leaves together, fold them longitudinally and feed on the green matter from inside, resulting in reduced photosynthetic activity [19]. Depending upon the crop stage, leaffolder can cause 22 per cent yield loss [18] with 63 to 80 per cent leaves damaged [1, 14]. Rice grain yield was reduced by 0.13g per tiller with 4.5 percent reduction in filled grain for every ten per cent increase of flag leaf damage [4]. Lactic acid bacteria (LAB) bestows human health [7] and are recognized as safe (GRAS) food - grade microorganisms. The genera *Carnobacterium, Enterococcus, Lactobacillus, Leuconostoc, Lactococcus, Pediococcus, Oenococcus, Streptococcus, Tetragenococcus, Vagococcus* and *Weissella* are exploited as probiotics, especially in fermented foods [22, 3]. They have also been exploited in crop production in many ways as biofertilizers, phytostimulators, rhizoremediators and biopesticides [17, 16]. They are also capable of degrading pesticides [25]. Despite integrated pest management technologies, insecticides are commonly used to manage rice leaffolder, resulting in resistance to insecticides, resurgence, secondary pest outbreak persistent residual toxicity, leading to environmental contamination [10, 12, 20, 24]. The present study was undertaken to evaluate the efficacy of a new insecticde formulation flubendiamide 20% WG in mixture with an LAB formulation against *C. medinalis*, predaceous coccinellids, spiders and rove beetles in rice, since the fermented products containing LAB are exploited as biofertilizers, biocontrol agents and biostimulants in agriculture, are often found in substrates rich in carbohydrates which they convert into organic acids and its volatiles are likely to modulate the beneficial insects in rice ecosystem.

Materials and Methods
Two field experiments were conducted at the Paddy Breeding Station, Tamil Nadu Agricultural University (TNAU), Coimbatore, one during the *Kharif* season (May 2018 - August 2018) and the other during the *Rabi* season (December 2018 - April 2019). Both experiments were carried out in a randomized blocks design (RBD) with six treatments

replicated four times. The plots were of 6 x 5 m^2 size with 1 m replication border and 0.5 m treatment border between the plots. Twenty day old Co 51 rice variety seedlings were transplanted at a spacing of 20×20 cm and regular agronomic practices were adopted in each season. The treatment details were as follows: T_1-Flubendiamide 20% WG @ 25 g a.i./ha,T_2-Flubendiamide 20% WG @ 50 g a.i./ha, T_3-Flubendiamide 20% WG @ 25 g a.i./ha + LAB @ 12.5% /ha, T_4-Flubendiamide 20% WG @ 50 g a.i./ha + LAB @ 12.5% /ha, T_5-LAB @ 12.5% /ha, T_6-Untreated check.

The semisolid lactic acid bacterial formulation was prepared through a process of discriminate fermentation [5] by mixing milk powder (100g) and cane jaggery (1.0 kg), fermented grape juice (100 ml) and beaten egg (1 number). To prepare the spray fluid, the formulated LAB was first diluted in water (4 parts), kept overnight and sprayed the next day at the rate of 25 ml per litre of water (i.e. 2.5%). The treatments as foliar spray were imposed twice, the first 35 days after transplanting (DAT) and the second 14 days later, with the help of a pneumatic knapsack sprayer using 500 l water / ha. No spray was made in the untreated plots. In both field trials, the injury to leaves by *C. medinalis* and the population of natural enemies such as spiders, rove beetles and coccinillid beetles were recorded from 10 randomly selected hills per plot at 7-day interval post treatment (DAT). The damage to leaves by leaffolder was assessed in percentage [8]. The data from all observations were subjected to appropriate statistical analysis after suitable transformations.

Results

C. medinalis

In both seasons the extent of damage caused by *C. medinalis* differed significantly among the treatments (Table 1 - 3). Pooled analysis of the two-season data indicated that the damage caused by *C. medinalis* was significantly lower in all plots than in untreated control plots (Table 3). Among the treatments, the injury was lowest in plots where flubendiamide 20 WG @ 50 g a.i. ha^{-1} + LAB was sprayed (3.09%), followed by flubendiamide 20 WG @ 50 g a.i. ha^{-1} (4.84%), flubendiamide 20 WG @ 25 g a.i. ha^{-1} + LAB (5.45%), and flubendiamide 20 WG @ 25 g a.i. ha^{-1}(7.2%) The damage was significantly lower in LAB-sprayed plots (15.33%) than in control plots (21.9%) but higher than that in other plots. Season wise too, flubendiamide 20 WG @ 50 g a.i. ha^{-1} + LAB was the most effective treatment (2.11 – 4.08%), followed by flubendiamide 20 WG @ 50 g a.i. ha^{-1} (3.77 – 5.91%), flubendiamide 20 WG @ 25 g a.i. ha^{-1} + LAB (4.5 – 6.4%), and flubendiamide 20 WG @ 25 g a.i. ha^{-1} (6.48 – 7.92%) (Table 1 & 2). Though effective, LAB when sprayed alone was inferior to flubendiamide with or without LAB (15.03 – 15.63%). Comparatively, flubendiamide 20 WG @ 50 g a.i. ha^{-1} + LAB reduced the damage by 82.16 – 89.93 per cent, flubendiamide 20 WG @ 50 g a.i. ha^{-1} by 74.17 - 81.96 per cent, flubendiamide 20% WG @ 25 g a.i. ha^{-1} + LAB by 72.03 – 78.48 per cent, flubendiamide 20% WG @ 25 g a.i. ha^{-1} 65.39 – 69.0 per cent, and LAB by 28.11 – 31.74 per cent, compared to the level of damaged leaves in control plots (Fig. 1).

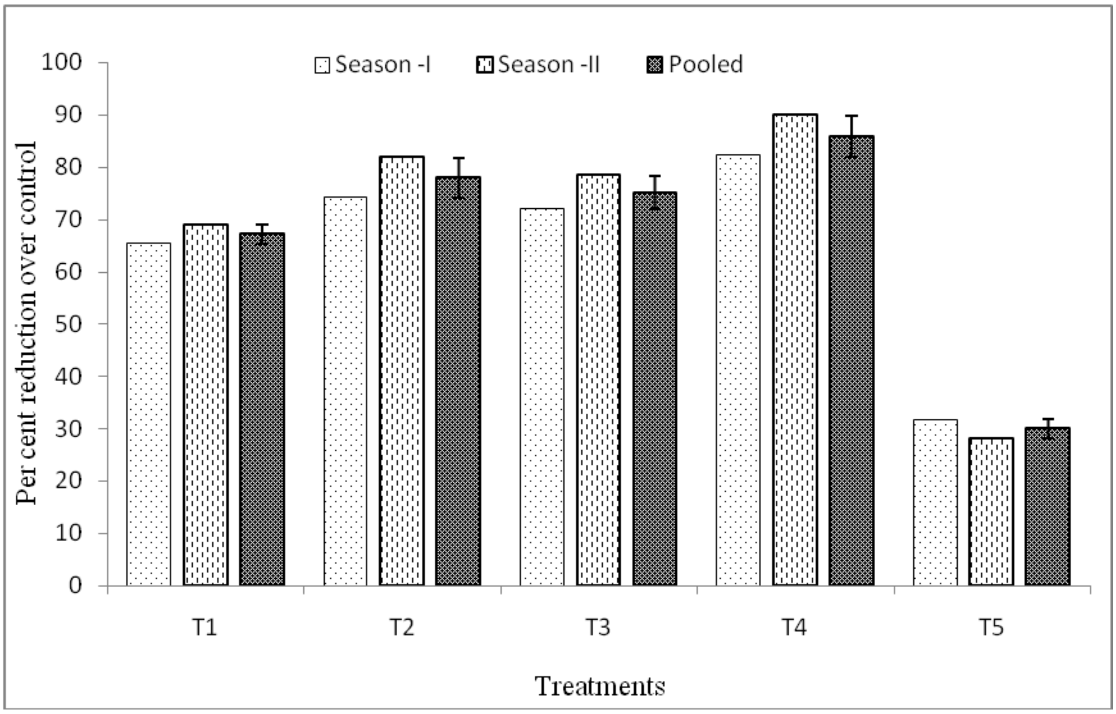

Fig 1: Per cent reduction over control on *C. medinalis* damage, Mean of two season data. T_1, Flubendiamide 20 WG @ 25 g a.i. /ha; T_2, Flubendiamide 20 WG @ 50 g a.i. /ha; T_3, Flubendiamide 20 WG @ 25 g a.i. /ha + LAB @ 12.5%/ha; T_4, Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 12.5% /ha; T_5, LAB alone @ 12.5%/ha. Vertical bars indicate the SE.

Natural Enemies

Populations of natural enemies, especially predatory coccinellids, spiders and rove beetles, were significantly less abundant on plants sprayed with fluebendiamide with or without LAB than on plants sprayed with LAB or no-spray control. In both seasons (Table 4 & 5), mixed species of coccinellid beetles were significantly less numerous on plants in plots treated with flubendiamide 20 WG @ 50 g a.i. ha^{-1} with or without LAB (1.19 – 1.21 / 10 hills in Season – 1 to 1.73 – 1.80 / 10 hills in Season – 2), followed by flubendiamide 20 WG @ 25 g a.i. ha^{-1} in mixture with or without LAB (1.87 – 2.19 / 10 hills in Season – 1 to 2.38 – 2.77 / 10 hills in Season – 2). The ladybirds were significantly most abundant on plants in plots where LAB was sprayed (3.03 / 10 hills in Season – 1 to 3.95 / 10 hills in Season – 2), followed by control (2.49 / 10 hills in Season – 1 to 3.4 / 10 hills in Season – 2). The pooled analysis of the data from the two seasons also indicated the same results with coccinellids being more numerous when LAB or none is sprayed (2.94 – 3.49 / 10 hills) than when flubendiamide was sprayed at low or high concentration with or without LAB (1.47 – 2.48 / 10 hills) (Table 6).

Similarly, spiders, *Oxyopes javanus* (Thorell) were also significantly fewer in plots treated with flubendiamide 20 WG @ 50 g a.i. ha^{-1} with or without LAB (2.73 – 2.87 / 10 hills in Season – 1 to 4.34 – 4.51 / 10 hills in Season – 2), followed by flubendiamide 20 WG @ 25 g a.i. ha^{-1} with or without LAB (3.87 – 4.31 / 10 hills in Season – 1 to 5.5 – 6.05 / 10 hills in Season – 2) than in control plots (5.65 / 10 hills in Season – 1 to 6.99 / 10 hills in Season – 2) and LAB-sprayed plots (6.32 / 10 hills in Season – 1 to 7.61 / 10 hills in Season – 2) (Table 7 & 8). The pooled means also indicated that spiders were more abundant in plots where LAB was sprayed (6.96 / 10 hills) as in control plots (6.32 / 10 hills) than in other plots (3.54 – 5.18 / 10 hills) (Table 9).

Rove beetles, *Paederus fusipes* (Curtis) were also significantly more on plants in LAB-sprayed plots (7.58 / 10 hills in Season – 1, 9.74 / 10 hills in Season – 2), followed by on plants in control plots (6.57 / 10 hills in Season – 1, 8.94 / 10 hills in Season – 2), than in other plots where flubendiamide was sprayed with or without LAB (4.48 – 5.61 / 10 hills in Season – 1 to 5.56 – 7.78 / 10 hills in Season – 2) (Table 10 & 11). The pooled two-season data also indicated the trend in abundance of rove beetles, more abundant after LAB spray (8.66 / 10 hills), followed by no-spray control (7.75 / 10 hills), than in flubendiamide sprays with or without LAB (5.02 – 6.70 / 10 hills) (Table 12).

Table 1: Effect of flubendiamide 20 WG and LAB on damage to leaves by *C. medinalis* in Season – 1

Treatments	Damaged leaves (%)						Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	11.19 (19.54)	8.84 (17.30)	10.02 (18.41)	7.12 (15.48)	4.54 (12.30)	5.83 (13.86)	7.92 (16.13)
Flubendiamide 20 WG @ 50 g a.i. /ha	9.33 (17.79)	7.19 (15.55)	8.26 (16.65)	4.75 (12.59)	2.38 (8.87)	3.57 (10.66)	5.91 (13.66)
Flubendiamide 20 WG@ 25 g a.i. /ha + LAB@ 12.5% /ha	9.79 (18.23)	7.93 (16.36)	8.86 (17.28)	5.17 (13.14)	2.72 (9.49)	3.95 (11.24)	6.40 (14.26)
Flubendiamide 20 WG @ 50 g a.i. /ha + LAB@ 12.5% /ha	7.51 (15.91)	5.18 (13.16)	6.35 (14.48)	2.65 (9.37)	0.99 (5.71)	1.82 (7.75)	4.08 (10.97)
LAB alone @ 12.5%/ha	14.31 (22.23)	15.83 (23.45)	15.07 (23.03)	16.41 (23.90)	15.95 (23.54)	16.18 (23.71)	15.63 (23.36)
Untreated check	18.82 (25.71)	21.53 (27.65)	20.18 (26.67)	24.16 (29.44)	27.06 (31.35)	25.61 (30.40)	22.89 (28.53)
Mean	11.83 (19.95)	11.08 (18.89)	11.45 (19.42)	10.04 (17.29)	8.94 (15.16)	9.49 (16.22)	10.47 (17.82)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.38	0.76	Treatments x DAS	:	0.54	1.07
Between DAS	:	0.22	0.44	Treatments x Spray	:	0.54	1.07
Between Spray	:	0.22	0.44	Treatments x DAS x Spray	:	0.76	1.51
DAS x Spray	:	0.31	0.62				

Table 2: Effect of flubendiamide 20 WG and LAB on leaf damage due to leaf folder in rice in season – 2

Treatments	Per cent leaf damage						Overall Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	8.73 (17.19)	7.95 (16.38)	8.34 (16.79)	5.49 (13.55)	3.75 (11.17)	4.62 (12.41)	6.48 (14.56)
Flubendiamide 20 WG@ 50 g a.i. /ha	5.56 (13.64)	4.73 (12.56)	5.15 (13.11)	3.27 (10.42)	1.52 (7.08)	2.40 (8.90)	3.77 (10.84)
Flubendiamide 20 WG@ 25 g a.i. /ha +LAB@ 12.5% /ha	7.31 (15.69)	5.19 (13.17)	6.25 (14.48)	3.64 (11.00)	1.85 (7.82)	2.75 (9.54)	4.50 (11.83)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB@ 12.5% /ha	4.73 (12.56)	2.06 (8.25)	3.40 (10.62)	0.94 (5.56)	0.69 (4.76)	0.82 (5.18)	2.11 (7.78)
LAB alone @ 12.5% /ha	13.66 (21.69)	14.05 (22.01)	13.86 (21.85)	16.41 (23.90)	15.98 (23.56)	16.20 (23.73)	15.03 (22.78)
Untreated check	16.16 (23.70)	19.71 (26.36)	17.94 (25.06)	22.68 (28.44)	25.06 (30.04)	23.87 (29.25)	20.90 (27.13)
Mean	9.36 (17.40)	8.95 (16.44)	9.15 (16.92)	8.74 (15.43)	8.14 (14.00)	8.44 (14.72)	8.80 (15.82)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.35	0.71	Treatments x DAS	:	0.50	1.00
Between DAS	:	0.20	0.41	Treatments x Spray	:	0.50	1.00
Between Spray	:	0.20	0.41	Treatments x DAS x Spray	:	0.71	1.41
DAS x Spray	:	0.29	0.58				

Table 3: Effect of flubendiamide 20 WG and LAB on leaf damage due to leaf folder in rice in Season – 1 & 2 (pooled)

Treatments	Per cent leaf damage						Pooled Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	9.96 (18.35)	8.40 (16.83)	9.18 (17.59)	6.31 (14.50)	4.15 (11.72)	5.23 (13.11)	7.20 (15.35)
Flubendiamide 20 WG @ 50 g a.i. /ha	7.45 (15.68)	5.96 (14.04)	6.70 (14.86)	4.01 (11.46)	1.95 (7.81)	2.98 (9.64)	4.84 (12.25)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB@ 12.5% /ha	8.55 (16.95)	6.56 (14.74)	7.56 (15.85)	4.41 (11.95)	2.29 (8.53)	3.35 (10.24)	5.45 (13.04)
Flubendiamide 20 WG @ 50 g a.i. /ha	6.12 (14.21)	3.62 (10.68)	4.87 (12.45)	1.80 (7.42)	0.84 (5.18)	1.32 (6.30)	3.09 (9.37)

+LAB@ 12.5% /ha							
LAB alone @ 12.5% /ha	13.99 (22.16)	14.94 (22.72)	14.46 (22.44)	16.41 (23.89)	15.97 (23.53)	16.40 (23.71)	15.33 (23.08)
Untreated check	17.49 (24.71)	20.62 (26.99)	19.06 (25.85)	23.42 (28.94)	26.06 (30.69)	24.74 (29.82)	21.90 (27.83)
Mean	10.59 (18.68)	10.02 (17.67)	10.30 (18.17)	9.39 (16.36)	8.54 (14.58)	8.97 (15.47)	9.63 (16.82)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of eight observations)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.26	0.51	Treatments x DAS	:	0.36	0.72
Between DAS	:	0.15	0.29	Treatments x Spray	:	0.36	0.36
Between Spray	:	0.15	0.29	Treatments x DAS x Spray	:	0.51	1.02
DAS x Spray	:	0.21	0.41				

Table 4: Effect of flubendiamide 20 WG and LAB on coccinellids in rice in season- 1

Treatments	Number of coccinellids per ten hills						Overall Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	1.43 (1.39)	1.99 (1.58)	1.71 (1.48)	1.72 (1.49)	2.35 (1.69)	2.04 (1.59)	1.87 (1.54)
Flubendiamide 20 WG@ 50 g a.i. /ha	0.95 (1.20)	1.34 (1.36)	1.15 (1.28)	1.06 (1.25)	1.49 (1.41)	1.28 (1.33)	1.21 (1.30)
Flubendiamide 20 WG@ 25 g a.i. /ha +LAB@ 12.5% /ha	1.64 (1.46)	2.27 (1.66)	1.96 (1.56)	2.11 (1.62)	2.74 (1.80)	2.43 (1.71)	2.19 (1.63)
Flubendiamide 20 WG@ 50 g a.i. /ha +LAB@ 12.5% /ha	0.88 (1.17)	1.53 (1.42)	1.21 (1.30)	0.97 (1.21)	1.36 (1.36)	1.17 (1.29)	1.19 (1.29)
LAB alone @ 12.5% /ha	2.27 (1.66)	2.79 (1.81)	2.53 (1.74)	3.25 (1.94)	3.81 (2.08)	3.53 (2.01)	3.03 (1.87)
Untreated check	1.83 (1.53)	2.32 (1.68)	2.08 (1.60)	2.64 (1.77)	3.15 (1.91)	2.90 (1.84)	2.49 (1.72)
Mean	1.50 (1.40)	2.04 (1.58)	1.77 (1.49)	1.96 (1.55)	2.48 (1.71)	2.22 (1.63)	2.00 (1.56)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are $\sqrt{x + 0.5}$ transformed values; mean of four replications)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.02	0.05	Treatments x DAS	:	0.03	0.07
Between DAS	:	0.01	0.03	Treatments x Spray	:	0.03	0.07
Between Spray	:	0.01	0.03	Treatments x DAS x Spray	:	0.05	0.10
DAS x Spray	:	0.02	0.04				

Table 5: Effect of flubendiamide 20 WG and LAB on Coccinellids in rice in season- 2

Treatments	Number of coccinellids per ten hills						Overall Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	2.17 (1.63)	2.52 (1.74)	2.345 (1.69)	2.13 (1.62)	2.68 (1.78)	2.41 (1.70)	2.38 (1.69)
Flubendiamide 20 WG@ 50 g a.i. /ha	1.51 (1.42)	1.99 (1.58)	1.75 (1.50)	1.56 (1.43)	1.86 (1.53)	1.71 (1.48)	1.73 (1.49)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB@12.5% /ha	2.33 (1.68)	2.85 (1.83)	2.59 (1.76)	2.61 (1.76)	3.27 (1.94)	2.94 (1.85)	2.77 (1.80)
Flubendiamide 20 WG @ 50 g a.i./ha +LAB@ 12.5% /ha	1.45 (1.39)	2.17 (1.63)	1.81 (1.01)	1.44 (1.39)	2.13 (1.62)	1.79 (1.51)	1.80 (1.51)
LAB alone @ 12.5% /ha	3.29 (1.95)	3.71 (2.05)	3.5 (2.00)	4.17 (2.16)	4.65 (2.27)	4.41 (2.21)	3.95 (2.11)
Untreated check	2.87 (1.84)	3.23 (1.93)	3.05 (1.88)	3.57 (2.02)	3.91 (2.00)	3.74 (2.06)	3.40 (1.97)
Mean	2.27 (1.65)	2.75 (1.79)	2.51 (1.72)	2.58 (1.73)	3.08 (1.87)	2.83 (1.80)	2.67 (1.76)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are $\sqrt{x + 0.5}$ transformed values; mean of four replications)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.02	0.05	Treatments x DAS	:	0.03	0.07
Between DAS	:	0.01	0.03	Treatments x Spray	:	0.03	0.07
Between Spray	:	0.01	0.04	Treatments x DAS x Spray	:	0.05	0.09
DAS x Spray	:	0.02	0.04				

Table 6: Effect of flubendiamide 20 WG and LAB on coccinellids in rice in pooled season- 1&2 (pooled)

Treatments	Mean of coccinellids per ten hills						Pooled Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	1.80 (1.51)	2.26 (1.66)	2.03 (1.58)	1.93 (1.56)	2.52 (1.74)	2.22 (1.65)	2.12 (1.61)
Flubendiamide 20 WG@ 50 g a.i. /ha	1.23 (1.31)	1.67 (1.47)	1.45 (1.39)	1.31 (1.34)	1.67 (1.47)	1.49 (1.41)	1.47 (1.40)
Flubendiamide 20 WG@ 25 g a.i. /ha +LAB@ 12.5% /ha	1.99 (1.57)	2.56 (1.75)	2.27 (1.66)	2.36 (1.69)	3.01 (1.87)	2.68 (1.78)	2.48 (1.72)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB@ 12.5% /ha	1.17 (1.28)	1.85 (1.53)	1.51 (1.40)	1.21 (1.30)	1.75 (1.49)	1.48 (1.40)	1.49 (1.40)
LAB alone @ 12.5% /ha	2.78 (1.80)	3.25 (1.93)	3.02 (1.87)	3.71 (2.05)	4.23 (2.17)	3.97 (2.11)	3.49 (1.99)
Untreated check	2.35 (1.68)	2.78 (1.80)	2.56 (1.74)	3.11 (1.89)	3.53 (2.00)	3.32 (1.95)	2.94 (1.85)
Mean	1.89 (1.53)	2.39 (1.69)	2.14 (1.61)	2.27 (1.64)	2.78 (1.79)	2.53 (1.71)	2.33 (1.66)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are $\sqrt{x + 0.5}$ transformed values; mean of eight observations)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.02	0.03	Treatments x DAS	:	0.02	0.05
Between DAS	:	0.01	0.02	Treatments x Spray	:	0.02	0.05
Between Spray	:	0.01	0.02	Treatments x DAS x Spray	:	0.03	0.07
DAS x Spray	:	0.01	0.03				

Table 7: Effect of flubendiamide 20 WG and LAB on spider, *Oxyopes javanus* in rice in season-1

Treatments	Number of *Oxyopes javanus* per ten hills						Overall Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	3.24 (1.93)	3.91 (2.10)	3.58 (2.02)	3.87 (2.09)	4.45 (2.23)	4.16 (2.16)	3.87 (2.09)
Flubendiamide 20 WG@ 50 g a.i. /ha	2.38 (1.69)	2.73 (1.80)	2.56 (2.75)	2.61 (1.75)	3.19 (1.92)	2.90 (1.84)	2.73 (1.97)
Flubendiamide 20 WG@ 25 g a.i. /ha +LAB@ 12.5% /ha	3.56 (2.01)	4.40 (2.21)	3.98 (2.11)	4.35 (2.20)	4.93 (2.33)	4.64 (2.27)	4.31 (2.19)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB@ 12.5% /ha	2.57 (1.75)	2.85 (1.83)	2.71 (2.79)	2.79 (1.81)	3.26 (1.94)	3.03 (1.88)	2.87 (1.83)
LAB alone @ 12.5% /ha	5.14 (2.34)	6.36 (2.62)	5.75 (2.50)	6.66 (2.67)	7.11 (2.76)	6.88 (2.72)	6.32 (2.61)
Untreated check	4.72 (2.28)	5.44 (2.43)	5.08 (2.36)	5.89 (2.53)	6.55 (2.65)	6.22 (2.59)	5.65 (2.48)
Mean	3.60 (2.01)	4.28 (2.17)	3.94 (2.09)	4.36 (2.18)	4.92 (2.30)	4.64 (2.24)	4.29 (2.16)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are $\sqrt{x+0.5}$ transformed values; mean of four replications)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.03	0.06	Treatments x DAS	:	0.04	0.08
Between DAS	:	0.02	0.03	Treatments x Spray	:	0.04	0.08
Between Spray	:	0.02	0.03	Treatments x DAS x Spray	:	0.06	0.12
DAS x Spray	:	0.02	0.05				

Table 8: Effect of flubendiamide 20 WG and LAB on spider, *Oxyopes javanus* in rice in season-2

Treatments	Number of *Oxyopes javanus* per ten hills						Overall Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	4.92 (2.33)	5.66 (2.48)	5.29 (2.40)	5.45 (2.44)	5.96 (2.54)	5.71 (2.49)	5.50 (2.45)
Flubendiamide 20 WG@ 50 g a.i. /ha	4.16 (2.16)	4.81 (2.30)	4.48 (2.33)	4.11 (2.15)	4.30 (2.19)	4.21 (2.17)	4.34 (2.20)
Flubendiamide 20 WG@ 25 g a.i. /ha +LAB@ 12.5% /ha	5.23 (2.39)	6.15 (2.58)	5.69 (2.49)	5.93 (2.53)	6.88 (2.72)	6.41 (2.62)	6.05 (2.56)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB@ 12.5% /ha	4.28 (2.19)	4.78 (2.30)	4.53 (2.24)	4.36 (2.20)	4.61 (2.26)	4.49 (2.23)	4.51 (2.24)
LAB alone @ 12.5% /ha	6.49 (2.64)	7.52 (2.83)	7.01 (2.74)	7.91 (2.90)	8.53 (3.01)	8.22 (2.95)	7.61 (2.84)
Untreated check	5.81 (2.51)	6.75 (2.69)	6.28 (2.60)	7.43 (2.82)	7.97 (2.21)	7.70 (2.86)	6.99 (2.73)
Mean	5.15 (2.35)	5.95 (2.53)	5.55 (2.45)	5.87 (2.51)	6.38 (2.60)	6.12 (2.55)	5.83 (2.50)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are $\sqrt{x+0.5}$ transformed values; mean of four replications)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.02	0.04	Treatments x DAS	:	0.03	0.06
Between DAS	:	0.01	0.03	Treatments x Spray	:	0.03	0.06
Between Spray	:	0.01	0.03	Treatments x DAS x Spray	:	0.04	0.09
DAS x Spray	:	0.02	0.04				

Table 9: Effect of flubendiamide 20 WG and LAB on spider, *Oxyopes javanus* in rice in pooled season -1&2 (pooled)

Treatments	Mean of *Oxyopes javanus* per ten hills						Pooled Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	4.08 (2.13)	4.79 (2.29)	4.43 (2.22)	4.66 (2.26)	5.21 (2.38)	4.93 (2.32)	4.68 (2.27)
Flubendiamide 20 WG@ 50 g a.i. /ha	3.27 (1.93)	3.77 (2.05)	3.52 (1.98)	3.36 (1.95)	3.75 (2.06)	3.55 (2.00)	3.54 (2.00)
Flubendiamide 20 WG@ 25 g a.i. /ha +LAB@ 12.5% /ha	4.39 (2.20)	5.28 (2.40)	4.83 (2.30)	5.14 (2.37)	5.91 (2.52)	5.52 (2.45)	5.18 (2.37)
Flubendiamide 20 WG@ 50 g a.i. /ha +LAB@ 12.5% /ha	3.43 (1.95)	3.82 (2.06)	3.62 (2.02)	3.58 (2.01)	3.94 (2.10)	3.76 (2.05)	3.69 (2.04)
LAB alone @ 12.5% /ha	5.82 (2.51)	6.94 (2.72)	6.38 (2.62)	7.28 (2.79)	7.82 (2.88)	7.55 (2.83)	6.96 (2.73)
Untreated check	5.27 (2.40)	6.10 (2.56)	5.68 (2.48)	6.66 (2.67)	7.26 (2.78)	6.96 (2.73)	6.32 (2.60)
Mean	4.37 (2.19)	5.11 (2.35)	4.74 (2.27)	5.11 (2.34)	5.65 (2.45	5.38 (2.40)	5.06 (2.33)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are $\sqrt{x+0.5}$ transformed values; mean of eight observations)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.02	0.03	Treatments x DAS	:	0.02	0.05
Between DAS	:	0.01	0.02	Treatments x Spray	:	0.02	0.05
Between Spray	:	0.01	0.02	Treatments x DAS x Spray	:	0.03	0.06
DAS x Spray	:	0.01	0.03				

Table 10: Effect of flubendiamide 20 WG and LAB on rove beetle, *Paederus fusipes* in rice in season-1

Treatments	Number of *Paederus fusipes* per ten hills						Overall Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	5.15 (2.37)	5.43 (2.43)	5.29 (2.40)	5.19 (2.39)	5.45 (2.44)	5.32 (2.41)	5.31 (2.41)
Flubendiamide 20 WG@ 50 g a.i. /ha	4.38 (2.21)	4.68 (2.27)	4.53 (2.24)	4.24 (2.18)	4.61 (2.26)	4.43 (2.22)	4.48 (2.23)
Flubendiamide 20 WG@ 25 g a.i. /ha +LAB@ 12.5% /ha	5.22 (2.39)	5.75 (2.50)	5.49 (2.27)	5.62 (2.47)	5.86 (2.52)	5.74 (2.50)	5.61 (2.47)
Flubendiamide 20 WG@ 50 g a.i. /ha +LAB@ 12.5% /ha	4.51 (2.24)	4.82 (2.31)	4.67 (2.74)	4.40 (2.21)	4.79 (2.30)	4.60 (2.26)	4.63 (2.26)
LAB alone @ 12.5% /ha	6.63 (2.67)	7.43 (2.82)	7.03 (2.57)	7.56 (2.83)	8.72 (3.04)	8.14 (2.94)	7.58 (2.84)
Untreated check	5.83 (2.52)	6.37 (2.62	6.10 (2.45	6.72 (2.69	7.35 (2.80	7.04 (2.74	6.57 (2.66)
Mean	5.29 (2.40)	5.75 (2.49	5.52 (2.45	5.62 (2.46	6.13 (2.56	5.88 (2.51	5.70 (2.48

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are $\sqrt{x+0.5}$ transformed values; mean of four replications)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.03	0.05	Treatments x DAS	:	0.04	0.07
Between DAS	:	0.01	0.03	Treatments x Spray	:	0.04	0.07
Between Spray	:	0.01	0.03	Treatments x DAS x Spray	:	0.05	0.11
DAS x Spray	:	0.02	0.04				

Table 11: Effect of flubendiamide 20 WG and LAB on rove beetle, *Paederus fusipes* in rice in season-2

Treatments	Number of *Paederus fusipes* per ten hills						Overall Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	6.93 (2.73)	7.34 (2.80)	7.14 (2.76)	6.80 (2.70)	7.23 (2.78)	7.02 (2.74)	7.08 (2.75)
Flubendiamide 20 WG@ 50 g a.i. /ha	5.36 (2.42)	5.75 (2.50)	5.56 (2.46)	5.39 (2.43)	5.72 (2.49)	5.56 (2.46)	5.56 (2.46)
Flubendiamide 20 WG@ 25 g a.i. /ha +LAB@ 12.5% /ha	7.38 (2.81)	7.71 (2.86)	7.55 (2.84)	7.55 (2.84)	8.49 (3.00)	8.02 (2.92)	7.78 (2.88)
Flubendiamide 20 WG@ 50 g a.i. /ha +LAB@ 12.5% /ha	5.41 (2.43)	5.88 (2.53)	5.65 (2.48)	5.52 (2.45)	5.86 (2.52)	5.69 (2.49)	5.67 (2.48)
LAB alone @ 12.5% /ha	8.75 (3.04)	9.67 (3.19)	9.21 (3.11)	9.98 (3.24)	10.57 (3.33)	10.28 (2.28)	9.74 (3.20)
Untreated check	8.22 (2.95)	8.73 (3.04)	8.48 (3.00)	9.15 (3.11)	9.64 (3.18)	9.40 (3.14)	8.94 (3.07)
Mean	7.01 (2.73)	7.51 (2.82)	7.26 (2.77)	7.40 (2.79)	7.92 (2.88)	7.66 (2.83)	7.46 (2.81)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are $\sqrt{x+0.5}$ transformed values; mean of four replications)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.02	0.05	Treatments x DAS	:	0.03	0.07
Between DAS	:	0.01	0.03	Treatments x Spray	:	0.03	0.07
Between Spray	:	0.01	0.03	Treatments x DAS x Spray	:	0.05	0.10
DAS x Spray	:	0.02	0.04				

Table 12: Effect of flubendiamide 20 WG and LAB on rove beetle, *Paederus fusipes* in rice in pooled season -1&2(pooled)

Treatments	Mean of *Paederus fusipes* per ten hills						Pooled Mean
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	6.04 (2.55)	6.39 (2.62)	6.21 (2.55)	6.00 (2.54)	6.34 (2.61)	6.17 (2.61)	6.19 (2.58)
Flubendiamide 20 WG@ 50 g a.i. /ha	4.87 (2.31)	5.22 (2.39)	5.04 (2.31)	4.82 (2.30)	5.17 (2.38	4.99 (2.38)	5.02 (2.34)
Flubendiamide 20 WG@ 25 g a.i. /ha +LAB@ 12.5% /ha	6.30 (2.60)	6.73 (2.68)	6.52 (2.63)	6.59 (2.65)	7.18 (2.76	6.88 (2.72)	6.70 (2.67)
Flubendiamide 20 WG@ 50 g a.i. /ha +LAB@ 12.5% /ha	4.96 (2.33)	5.35 (2.42)	5.16 (2.33)	4.96 (2.33)	5.33 (2.42	5.14 (2.41)	5.15 (2.37)
LAB alone @ 12.5% /ha	7.69 (2.85)	8.55 (3.00)	8.12 (2.95)	8.77 (3.04)	9.65 (3.18	9.21 (3.07)	8.66 (3.02)
Untreated check	7.03 (2.73)	7.55 (2.83)	7.29 (2.82)	7.94 (2.90)	8.50 (2.99	8.22 (2.91)	7.75 (2.86)
Mean	6.15 (2.56)	6.63 (2.66)	6.39 (2.61)	6.51 (2.63)	7.02 (2.72)	6.77(2.67)	6.58 (2.64)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are $\sqrt{x+0.5}$ transformed values; mean of light observations)

		SE.d	CD (P=0.05)			SE.d	CD (P=0.05)
Between Treatments	:	0.02	0.04	Treatments x DAS	:	0.03	0.05
Between DAS	:	0.01	0.02	Treatments x Spray	:	0.03	0.05
Between Spray	:	0.01	0.02	Treatments x DAS x Spray	:	0.04	0.07
DAS x Spray	:	0.01	0.03				

Discussion

Flubendiamide 20 WG is a new formulation effective against Lepidoptera. Evaluation of this formulation in field trials revealed that at the higher 50 g a.i. ha^{-1} dose it was significantly more effective in reducing the leaf damage caused by *C. medinalis* as high as 74.17 - 81.96 per cent. A different formulation, flubendiamide 480 SC @ 24 and 30 g a.i./ha has been highly effective against rice leaffolder at various places [21, 15, 11, 16, 19]. However, Flubendiamide 20 WG @ 50 g a.i. ha^{-1} was even more effective when LAB was mixed with this formulation (82.16 – 89.93%). Similarly, at the lower 25 g a.i. ha^{-1} dose, it reduced the injury by 65.39 – 69.0 per cent. However, with LAB as an additive, it lowered the damage by 72.03 – 78.48 per cent. This indicates that LAB was able to increase the efficacy of flubendiamide by 7 – 8 per cent, probably because of its adjuvant qualities such as better wetting, sticking, spreading and less spray drifting. It is also probable that LAB itself help reduce the damage by a significant level (28.11 – 31.74%), compared to the untreated check as observed in the trials. It may be noted that LAB are ubiquitous members of many plant microbiomes and ferments containing LAB are exploited in agriculture as biofertilizers, biocontrol agents and biostimulants [13]. They are gram positive, facultative anaerobic bacteria often found in substrates rich in carbohydrates which they convert into organic acids. However, different species of LAB occur as epiphytics [9]. *Lactobacilli* are found in phyllosphere, endosphere and rhizosphere of many plants [13]. Though how LAB reduced the leaf damage due to *C. medinalis* is not known, its volatiles are likely to modulate the insect numbers on plants, especially beneficial insects as recorded in the experimental plots, significantly more in LAB-sprayed plots than in all other plots, including unsprayed control. For instance, the predatory coccinellids, spiders and rove beetles were consistently more numerous after LAB spray than flubeniamide alone, either at lower or higher concentrations. However there was increase in reduction of *C. medinalis* damage when LAB was mixed with flubendiamide (Fig 1). Thus when mixed to flubendiamide, LAB appeared to have reduced flubendiamide toxicity only to these beneficial insects but not to *C. medinalis*, i.e. LAB is safer to natural enemies even when mixed with pesticides like flubendiamide. Earlier reports also suggest that flubendiamide is less toxic to beneficial arthropods in rice ecosystem [23, 15]. It may be concluded that *C. medinalis* can be managed more effectively by spraying flubendiamide 20 WG @ 25 or 50 g a.i. ha^{-1} in combination with the formulated LAB 12.5% which is comparatively safer to natural enemies.

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